Page 279

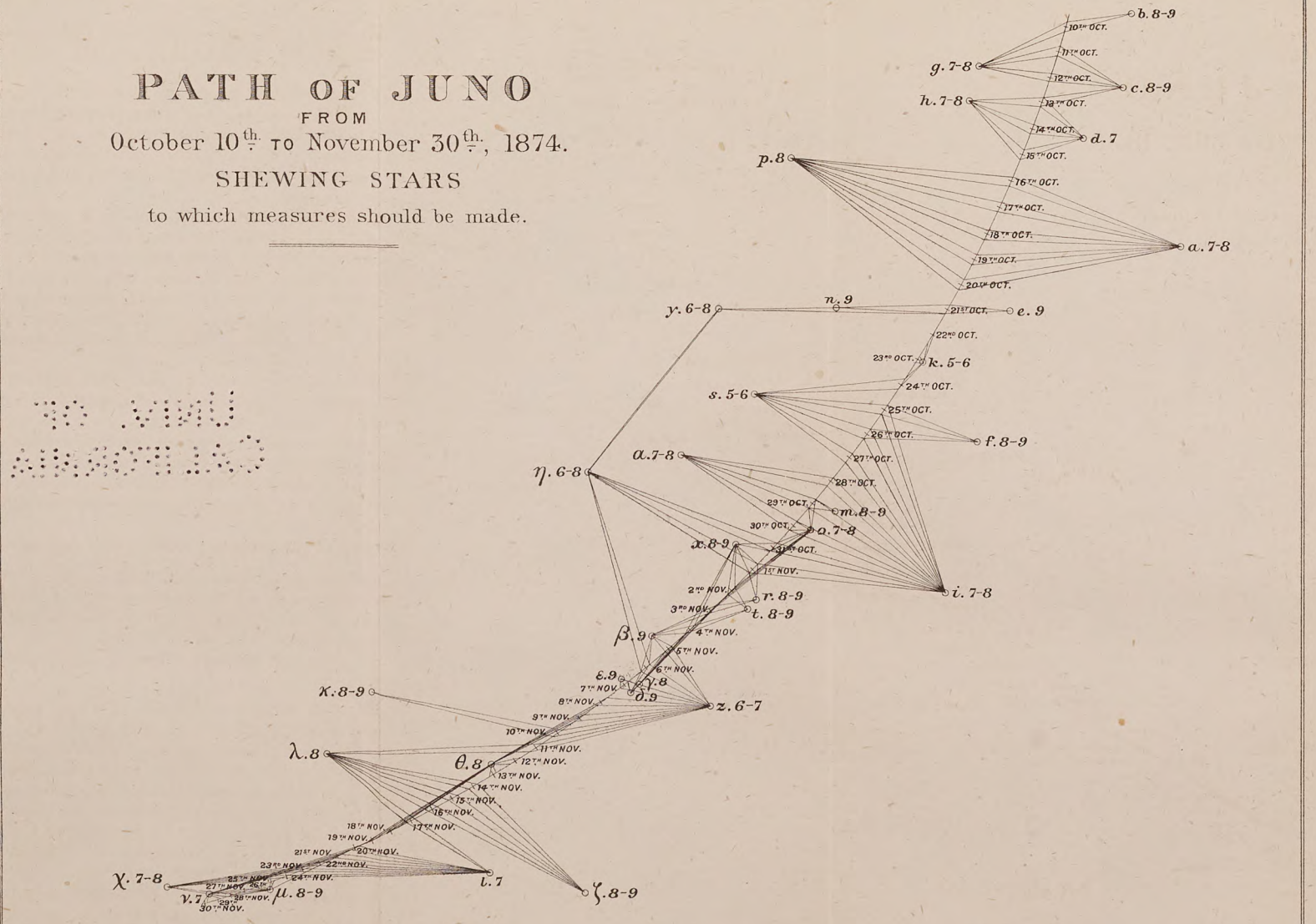
PATH OF JUNO

FROM

October 10th. to November 30th., 1874.

SHEWING STARS

to which measures should be made.



Malby & Sons, Lith.

Digitized by Google

On the Determination of the Solar Parallax by Observations of Juno at Opposition. By Lord Lindsay and Mr. David Gill.

Dr. Galle has already proposed (*Astron. Nach.*, vol. lxxx. p. 1), a method of obtaining the solar parallax, by observing, with a wire micrometer simultaneously at a northern and southern observatory, the difference of declination between a minor planet and two stars near the planet, and nearly equally north and south from it.

The method recommends itself, not by a favourable factor of parallax such as is afforded by a transit of *Venus* or a favourable opposition of *Mars*, but by the extreme precision with which a minute point of light can be bisected as compared with that with which a web can be brought into contact with a disk.

We are not aware that any results have been published of the application of the method, though there is no doubt that it is capable of great accuracy.

It has appeared to us that if we can select suitable stars, and observe the parallactic displacement of a minor planet relative to these stars by the Earth's rotation, we have a method of determining the solar parallax, which is free from the difficulties and disappointments attending observations in which co-operation is necessary, and where the most complete arrangements and perfect observation may be upset by unfavourable weather at the opposite station.

The accuracy of the proposed method will depend—

1. On the amount of displacement that can be measured.
2. The accuracy with which the measures can be made.
3. The number of nights on which the measures can be repeated, which will partly depend on the nights on which suitably situated stars of comparison can be found.

The planet *Juno* at the opposition of 1874 appears to be very favourably situated for a trial of this method. Mauritius (the station where we observe the transit of *Venus*) a suitable position, and the Repsold Heliometer, with which the transit is to be observed, a suitable instrument. We have accordingly investigated the conditions of probable attainable accuracy as follows, and trust the results may be acceptable to the Society.

Juno, in opposition on 5th November, 1874, has a horizontal parallax of $8''\cdot7$, and south declination of $3^\circ\cdot5'$.

If we suppose that we may begin to measure when the planet has an altitude of 20°, and continue till the altitude is 40°; and at setting begin to measure at an altitude of 40°, and observe till the planet's altitude is 20°: then for opposition we have—

Digitized by Google

Altitude. °	Parallax in A.R. ″	Hour Angle. h m
20	7·70	4 41
30	7·05	
40	6·14	3 15
	Time available for observation	1 26

In other words, we shall be able to observe a displacement of about 14″, and have 86 minutes both at rising and setting during which we may make observations.

The observations can be made with advantage for a month preceding and a month following opposition.

It will not be possible to observe the planet at so large an hour angle in the early mornings a month before opposition, as the sun rises when the hour angle of the planet is about three hours and a half; nor similarly a month after opposition shall we be able to commence observation so early as is desirable, and moreover the horizontal parallax will be a little less. Notwithstanding this, for fifty nights an average parallactic displacement in A.R. of about 12″ can be obtained.

In the list of stars which we have prepared for comparison with *Juno*, distances will be found considerably exceeding those usually measured with the heliometer.

So far as we know, *Bessel* seldom, if ever, measured distances equal to 3000″, and at Oxford the greatest distances measured with the heliometer have been under that amount.

In the Königsberg heliometer (*Bessel's*), the divided lenses being mounted in plain slides, distortion of the image resulted when large angles had to be measured; but in the construction of the new Repsold heliometer, as also in the Oxford heliometer by the same makers, the lenses move in slides of circular curvature in the direction of their length, the centre of curvature being the focal point of the object-glass.

The effect of this arrangement is, that whatever the separation of the segments of the object-glass, the images are equally free from distortion, and so far as the optical qualities of the instrument are concerned, a large angle can be measured with equal accuracy with a small one.

In the use of the Oxford heliometer, as in the Königsberg instrument, one segment of the object-glass remains fixed, and the other is used for measurement on opposite sides of the fixed segment.

In this way the extent of angle which the instrument is capable of measuring is limited by the amount which one segment can be moved on either side of zero.

In the more modern form of the Repsold heliometer* both

* Astronomy is indebted to Drs. Struve, Auwers, and Winnecke for the arrangement of this instrument. Similar heliometers are to be employed by Russia for observation of the transit of *Venus*.

Digitized by Google

halves of the divided object-glass are moved in equal and opposite directions by a single movement, and thus the extent of angle which can be measured is doubled, and the instrument can measure completely an angle of 2°.

The symmetry thus given to the observation also facilitates the reduction of the observations and adds to their accuracy, but to this we need not further allude at present. It will be sufficient to show with what precision such angles can be measured, and what precautions are necessary to attain the highest possible accuracy.

In illustration, we give the following observations recently made by Mr. Gill, at Dunecht Observatory, on a zone of stars in *Perseus* * to determine the value of the scale of the instrument, the distances and magnitudes of the stars being very similar to those which occur in the list of stars to be measured with *Juno*.

The *first* column contains the date of observation.

The *second*, the hour angle of observation.

The *third*, the distance converted into arc on an assumed approximate value of the heliometer scale.

The *fourth*, the sum of the corrections for aberration and refraction (the effect of the barometer and thermometer on the refraction has been included).

The *fifth*, the resulting distance.

The *sixth*, the mean of each successive pair of observations which constitute a *complete* measure. (See note * on next page.)

The *seventh*, the difference of the *complete* observation from the mean of the *complete* observations of the same evening.

The *eighth*, the difference from the mean of all the observations of the same object.

The *ninth*, the temperature at the time of observation.

* The stars are as follow:—

	Mag.	A.R. h m s	Decl. ° ′
a	6·8	3 8 55	+40 1·2
b	7·5	3 5 53	39 37·7
c	5·2	3 3 7	39 7·9
d	8·1	2 59 26	38 34·9
e	5 var.	2 57 4	38 20·8
f	6·8	2 53 50	38 23·8
g	6·0	2 50 2	38 5·7
h	6·0	2 45 44	37 49·3
i	4·8	2 42 36	37 47·2
k	7·0	2 39 35	37 16·2

The successive distances and position-angles of these stars having been measured, the distances are projected on the great circle joining the extreme stars, and the result so obtained is compared with the distance obtained by Meridian observation of the extreme stars. The same stars have been observed by the German heliometer observers of the transit of *Venus*. The same

Digitized by Google

c—*e*

I. Date.	II. Hour Angle.	III. Observed Distance.	IV. Correction for Refraction and Aberration.	V. Resulting Distance.	VI.	VII.	VIII.	IX.
	h m	"	"	"	"	"	"	° ′
Feb. 3	1 10·3	5094·811	+1·663	5096·474	5096·276	...	0·358	38 3
	1 19·5	5094·386	1·691	5096 077				
Feb. 10	3 13·9	5094·669	2·261	5096·930	5096·774	0·022	0·140	29 0
	3 23·0	5094·286	2·331	5096·617				
	3 33·3	5094·095	2·423	5096·518	5096·818	0·022	0·184	
	3 39·8	5094·582	2·536	5097·118				
Feb. 16	2 36·9	5094·618	1·897	5096·515	5096·564	0·141	0·070	40 0
	2 43·5	5094·677	1·935	5096·612				
	2 57·5	5094·360	2·017	5096·377	5096·282	0·141	0·352	
	3 4·0	5094·131	2·055	5096·186				
Feb. 19	2 22·5	5095·202	1·885	5097·087	5096·913	0·050	0·279	40 5
	2 29·0	5094·826	1·913	5096·739				
	3 26·5	5094·710	2·282	5096·992	5096·814	0·050	0·180	380
	3 32·5	5094·301	2·335	5096·636				

e—*g*

Feb. 10	1 33·0	5061·521	−1·628	5063·149	5063·063	0·099	0·066	28 0
	1 40·7	5061·328	1·648	5062·976				
	1 53·5	5061·925	1·689	5063·614	5063·261	0·099	0·264	
	2 1·2	5061·210	1·698	5062·908				
Feb. 13	2 28·1	5061·223	1·678	5062·901	5063·022	0·136	0·025	40 2
	2 36·9	5061·421	1·721	5063·142				
	2 46·1	5061·151	1·748	5062·899	5062·750	0·136	0·247	
	2 53·1	5060·824	1·777	5062·601				

places for the extreme stars will be assumed in the reductions, and the values of the scales of the heliometers so obtained will thus be strictly comparable, and a small absolute error in their values would have no effect on the transit of *Venus* observations. The star *a* has been rejected, as it is a difficult double star, and *b* to *k* are the extreme stars.

* The observations are made thus

with the halves of the object-glass as sketched. Observations 1 and 2 give one measure, and 3, 4 another; but as the zero of the microscope is continually changing from flexure, it is necessary to make the observations in this order to eliminate the effect of this change.

Digitized by Google

I. Date.	II. Hour Angle.	III. Observed Distance.	IV. Corr. for Refraction and Aberration.	V. Resulting Distance.	VI.	VII.	VIII.	IX.
	h m	"	"	"	'	"	"	° '
Feb. 18	3 48·2	5060·811	2·143	5062·954	5062·890	...	0·107	35 0
	3 55·0	5060·636	2·190	5062·826				
			h—i					
Jan. 9	22 37·5	2226·448	+0·614	2227·062	2227·218	...	0·211	38 0
	22 56·1	2226·757	0·616	2227·373				
Jan. 24	0 36·2	2225·939	0·665	2226·604	2226·878	0·024	0·129	31 0
	0 45·7	2226·479	0·673	2227·152				
	1 3·9	2226·366	0·693	2227·059	2226·926	0·024	0·081	
	1 16·2	2226·095	0·697	2226·792				
			g—h					
Jan. 9	23 26·5	3213·297	+0·908	3214·205	3214·400	0·168	0·044	39 0
	23 38·6	3213·685	0·909	3214·594				
	23 58·1	3213·438	0·914	3214·352	3214·063	0·168	0·293	
	0 9·8	3212·856	0·918	3213·774				
Jan. 24	1 35·0	3213·029	1·055	3214·084	3214·147	0·227	0·209	30 7
	1 44·3	3213·139	1·070	3214·209				
	1 55·5	3213·477	1·093	3214·570	3214·600	0·227	0·244	
	2 5·8	3213·508	1·121	3214·629				
Feb. 16	3 55·0	3213·379	1·463	3214·842	3214·568	...	0·212	39 8
	4 5·9	3212·766	1·527	3214·293				
			h—k					
Feb. 10	2 32·8	4841·915	+1·868	4843·783	4843·766	0·089	0·428	28 0
	2 42·8	4841·828	1·921	4843·749				
	2 58·3	4841·380	2·013	4843·393	4843·589	0·089	0·605	
	3 6·9	4841·715	2·070	4843·785				
Feb. 13	4 21·7	4841·424	2·575	4843·999	4844·195	...	0·001	41 3
	4 28·1	4841·735	2·656	4844·391				
Feb. 16	4 32·5	4842·309	2·719	4845·028	4844·546	0·165	0·352	39 0
	4 41·3	4841·202	2·861	4844·063				
	4 52·3	4842·664	3·065	4845·729	4844·876	0·165	0·682	
	5 2·2	4840·742	3·280	4844·022				
			b—c					
Jan. 4	0 47·9	2683·868	+0·867	2684·735	2684·937	0·013	0·149	31 0
	1 0·9	2684·260	0·878	2685·138				

Digitized by Google

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Date.	Hour Angle.	Observed Distance.	Corr. for Refraction and Aberration.	Resulting Distance.				
	h m	"	"	"	"	"	"	° ′
	1 20·6	2684·131	0·899	2685·030	2684·962	0·013	0·124	
	1 37·3	2683·964	0·930	2684·894				
Feb. 3	1 36·8	2684·528	0·923	2685·451	2685·440	0·097	0·354	38 0
	1 44·5	2684·489	0·940	2685·429				
	1 54·0	2683·660	0·958	2684·618	2685·247	0·097	0·162	
	2 0·3	2684·903	0·972	2685·875				
Feb. 28	2 53·4	2683·940	1·082	2685·022	2684·942	0·022	0·144	41 0
	3 0·9	2683·753	1·108	2684·861				
	3 11·3	2684·038	1·142	2685·180	2684·985	0·022	0·101	
	3 19·0	2683·616	1·174	2684·790				
			c—d					
Feb. 3	2 28·0	3222·782	+1·246	3224·028	3223·494	0·054		37 6
	2 34·2	3221·693	1·266	3222·959				
	2 42·9	3222·710	1·296	3224·006	3223·602	0·054		
	2 52·8	3221·871	1·327	3223·198				
			e—f					
Jan. 9	1 28·5	2291·022	+0·677	2291·699	2291·465	0·202	0·303	38 0
	1 36·7	2290·551	0·680	2291·231				
	1 49·4	2290·865	0·689	2291·554	2291·869	0·202	0·101	
	2 0·4	2291·485	0·698	2292·183				
Jan. 25	1 56·1	2291·061	0·694	2291·755	2291·966	...	0·198	44 5
	2 12·4	2291·470	0·707	2292·177				
Feb. 4	0 10·1	2291·053	0·661	2291·714	2291·727	0·043	0·041	43 5
	0 19·4	2291·076	0·664	2291·740				
	0 49·6	2291·210	0·672	2291·882	2291·812	0·043	0·044	
	0 57·6	2291·068	0·674	2291·742				
			f—g					
Jan. 9	0 39·7	2863·227	+0·657	2863·884	2863·537	0·182	0·186	38 5
	0 48·2	2862·530	0·659	2863·189				
	1 5·3	2862·167	0·660	2862·827	2863·173	0·182	0·178	
	1 15·2	2862·849	0·669	2863·518				
Jan. 25	1 9·9	2862·471	0·665	2863·136	2863·464	0·117	0·113	44 5
	1 17·9	2863·122	0·670	2863·792				
	1 36·9	2862·484	0·682	2863·166	2863·231	0·117	0·120	
	1 45·3	2862·610	0·685	2863·295				

Digitized by Google

d—e

I. Date.	II. Hour Angle.	III. Observed Distance.	IV. Corr. for Refraction and Aberration.	V. Resulting Distance.	VI.	VII.	VIII.	IX.
	h m	"	"	"	"	"	"	° ′
Feb. 3	3 14·8	1885·239	+0·820	1886·059	1886·439	...	...	37 0
	3 22·1	1885·980	0·838	1886·818				

i—k

Jan. 4	23 18·5	2905·021	+0·875	2905·896	2906·166	0·075	0·051	30 0
	23 33·1	2905·552	0·884	2906·436				
	23 50·9	2905·261	0·893	2906·154	2906·315	0·075	0·200	
	0 4·7	2905·572	0·904	2906·476				
Jan. 17	23 9·4	2905·166	0·842	2906·008	2905·953	0·093	0·162	32 0
	23 24·9	2905·045	0·852	2905·897				
	23 41·5	2904·697	0·860	2905·557	2905·769	0·093	0·346	
	23 54·0	2905·117	0·863	2905·980				
March 4	2 48·6	2905·209	1·195	2906·404	2906·361	0·169	0·246	47 3
	2 58·8	2905·081	1·237	2906·318				
	3 11·0	2904·728	1·295	2906·023	2906·124	0·169	0·009	
	3 18·6	2904·887	1·337	2906·224				

If we examine the seventh column, which contains the difference of each complete observation from the mean of the complete observations of the same evening, and compare these differences with those in the eighth column, where we have the difference of each complete observation from the mean of the whole observations made on the same stars, we find, as we should expect, that the observations of the same evening agree with each other much more closely than those of different evenings.

Dividing the stars into three groups, according to their distances, we find by the method of least squares the probable error from the residuals of column VII. between observations of the same object made within a short interval of each other, representing *very nearly* the probable error of *pointage* (which includes the error in making coincidence of the images of the stars and error in reading the scales *) and from the residuals in column VIII. the probable error of measure, including errors produced by temperature, &c., on different evenings. The results are:

* The error of runs is practically eliminated in the method of observation by observing the division which precedes as well as that which follows the zero of the microscope.

Digitized by Google

	Mean Distance.	Probable Error by Column VII.	Probable Error by Column VIII.
	"	"	"
Group I.	2401	0·069	0·123
Group II.	3052	0·088	0·137
Group III.	5001	0·081	0·220

We find from these "probable errors" a confirmation of what we previously stated, that the error of *pointage* is hardly affected by the distance of the objects, whilst the other errors of observation from night to night vary nearly proportionally with the distance between the stars.

It becomes important to consider very fully what are these sources of error which in the observation of stars of about 5000″ distance increase the probable error of observation nearly three-fold.

The errors to which an observation with the heliometer is subject, beyond those of *pointage*, appear to be due to—1st, Temperature. 2nd. Maladjustment of the focal point. 3rd. Errors of division of the scales. 4th. Errors of the micrometer screw, used to subdivide the scale intervals. 5th. Error of the absolute value of the scale at the standard temperature.

Of these, we shall at present only deal with 1 and 2; 3 and 4 will also to a small extent affect the results, as two observations of the same evening are usually made with the position circle reversed, and the flexure of the tube as well as a small "loss of time" in the slow motion of the segments of the object-glass combine to change the zero of the microscope somewhat, and so a different part of the micrometer screw is used in the measures, and even sometimes another division. The investigation of the errors of the micrometer screw are not yet complete, but the effect of their application can only be to diminish very slightly the probable error. 5. Can only affect us where *absolute* results are required, and these do not enter into the question before us.

To obtain some first approximate idea of the temperature correction, we took the intervals of the stars observed at the highest temperature and compared them with the intervals of lowest temperature, as follows—dividing the observations into two series, one of double, the other of single intervals:

Distance.	Temperature.	Distance.	Temperature.	Difference.
"	° ′	"	° ′	
5096·796	29 0 F.	5096·864	39 0 F.	+·00133
5063·162	28 0 „	5062·886	40 2 „	−·00447
4843·678	28 0 „	4844·195	41 3 „	+·00803
2226·902	31 0 „	2227·218	38 0 „	+·02024
3214·397	30 7 „	3214·230	39 0 „	−·00614
2684·950	31 0 „	2684·964	41 0 „	+·00052
2291·667	38 0 „	2291·770	43 5 „	+·00814
2863·355	38 5 „	2863·348	44 5 „	−·00041
2906·241	30 0 „	2906·293	47 0 „	+·00004

Digitized by Google

From these we obtain the following results, having regard to the distances and temperatures:

1st Series, effect of + 1° F. on 1000″ distance = + 0″·00174
2nd Series, „ „ „ „ = + 0″·00189

It is evident, however, from inspection of the residuals that this close coincidence of results is greatly indebted to chance, and the only conclusion we can draw from it is that the temperature correction of the instrument is excessively small, and that a very much greater range of temperature than that afforded by the recent mild winter will be necessary to obtain this coefficient with the desirable accuracy.

If we consider in what way temperature affects the value of the heliometer scale, we shall see why this coefficient is so small. The value of the scale depends on the proportion which the length of the scale bears to the focal length of the telescope.

This scale being of silver the effect of temperature on it will be represented by the usual coefficient of expansion of that metal. The effect of temperature on the focal length of the object-glass has been measured as follows:—In the common focus of the object-glass and eye-piece are cross webs. To the frame carrying these webs is attached a scale, divided into $\frac{1}{10}$ of millimètres, and these divisions can be read by estimation to $\frac{1}{100}$ of a millimètre relative to a line engraved on a block attached to the brass tube of the telescope, so that the readings of the focal point by this scale at different temperatures give measures of the focal point relative to the brass tube of the instrument.

The following are the results of these measures:

Temperature.	No. of Obs.	Millim.
32°–36° F.	23	7·940
38–42 „	41	7·937
42–48 „	21	7·934

The lengthening of the focus of the object by heat, is thus found to be practically equal to the expansion of the brass tube of the instrument.

This law appears to hold good with many instruments. Struve found the same with the Prime Vertical Transit at Pulkowa, and the German heliometer observers have found similar results with their instruments. The temperature coefficient of the instrument is therefore equal to—

(" coefficient of expansion of silver ")—(coefficient of expansion of brass).

If we take the coefficient of expansion for 1° F. for

Silver = ·00001060
Brass = ·00001044

Digitized by Google

the temperature coefficient of the instrument will be + ·00000016, or for our former unit of 1000″ = 0″·00016 for 1° F.

This quantity is so minute as to be almost insensible in the largest angles and greatest differences of temperature likely to be measured, amounting only to 0″·056 for a distance of 5000″ and a difference of 70° from mean temperature. As the silver of the scale is probably alloyed with copper, whose expansion is lower than that of brass, it is probable that the expansion of the scale is somewhat less than we have assumed and the equality of expansion of the scale and tube even still more perfect.

It is quite otherwise, however, when there is a *difference* of temperature between the object-glass and scale: then the excess of the temperature of the scale over that of the object-glass will increase its value in direct proportion to the excess of temperature and coefficient of the scale's expansion. Thus, if the temperature of the scale exceeds that of the object-glass by 5° F. the increase of the value of the scale (that is, the diminution of its reading) is 0″·261 on a distance of 5000.″

We shall now examine the effects of the maladjustment of the focus.

Suppose a measure correctly made at the proper focus, let s be the distance observed, f the focal length of the heliometer. If we now suppose the observer's eye to have no accommodation and remove the eye-piece from the object-glass by a very small amount $= \frac{f}{n}$, we shall disturb the coincidence of the images, and to restore that coincidence shall have to separate the divided segments still further by an amount $= \frac{s}{n}$, so that for an observation where the focal point is too great by an amount $= \frac{f}{n}$, the correction will be $= -\frac{s}{n}$ . . . . . (1).

As in observations of stars there is generally little difference between the temperature of the object-glass and that of the tube, it has been usual to make all the measures using the same readings of the focal scale, so that the position of the focal point with respect to the cross webs depends on the difference in temperature of the tube and object-glass.

If we denote—

t^g = temperature of the object-glass,
t^s = ,, ,, ,, scale,
t^t = ,, ,, ,, tube,
t = normal temperature at which the focal point is adjusted and scale value determined,
x = coefficient of expansion of scale,
y = ,, ,, ,, ,, tube,
z = lengthening of focal length of object-glass by 1° F.,
s = distance measured,

Digitized by Google

we shall have—

Correction for temperature of scale $= + x\,(t^s - t)\,s$.

If we put $x = y + \Delta y$,

The correction becomes $= -y\,(t^s - t)\,s + \Delta y\,(t^s - t)\,s$ . . . (2).

The correction for temperature of the object-glass is $= -z(t^s - t)\,s$.

But since $z = y$ the correction may be written $=$

$-y(t^s - t)\,s$ . . . . . (3).

Since the focal point is adjusted for temperature t, we must employ a correction for the displacement.

The increase of the length of the tube is $f\,(t^t - t)\,y$.

And that of the focus of object-glass

$$= f\,(t^s - t)\,z = f(t^s - t)\,y.$$

The difference is the distance which the eye-piece will be removed beyond the focal point $\left(\frac{f}{n}\right) = f\,(t^t - t^g)\,y$.

But by (1) the correction for $\frac{f}{n} = -\frac{s}{n}$.

Hence the correction for displacement of focus becomes

$-y\,s\,(t^t - t^g)$ . . . . . (4).

The sum of these corrections, 2, 3, and 4, is the correction to be applied to an observation.

$$2 = -syt^g + syt$$

$$3 = +syt^s - syt + \Delta y.(t^s - t)\,s$$

$$4 = -syt^t + syt^g$$

The sum of which is—

$$sy(t^s - t^t) + \Delta y(t^s - t)\,s$$

Thus we see it is only necessary to observe the temperatures of the scale and tube in order to eliminate all the effects of temperature on the measures, *if we assume that the eye has no accommodation.*

This could almost be done for very minute quantities if we could illuminate the field, and focus the eye on the wires immediately before measuring; but in the measurement of 8th and 9th magnitude stars it is necessary to employ a perfectly dark field. Some small systematic errors therefore creep in on this account, and it will be necessary so to arrange the stars of comparison and the order of observation that this may be eliminated as far as possible.

In constructing the following list we have endeavoured to select stars of nearly equal declination, and equally opposite A.R. from the planet, and sufficiently bright for observation. If this condition could be fulfilled in every case, the observations would be subject to no systematic error. It is intended, both at rising and setting, to make first one *complete* comparison with the star preceding the planet, next one with the star following, again another with the star following, and finally one with the star

Digitized by Google

preceding. In this way the effect of any constantly increasing instrumental change will be completely eliminated. The effect of a minute change in the value of the scale between rising and setting will be to give too large a parallax by one of the stars, and too small a parallax by the other, the mean would be free from systematic error. It has, of course, been impossible to select stars strictly fulfilling this condition; generally, at least, the stars are on nearly exactly opposite sides of the planet, though not exactly in the same parallel of A.R., in which case the parallactic displacement will depend to some extent on the position-angles. If the stars are strictly opposite and equally distant from the planet, a change of zero of the position circle is completely eliminated in the mean result. A glance at the accompanying map will show how we have endeavoured to overcome systematic errors by the arrangement of the stars of comparison. On several occasions where the star is very close to the planet, the systematic error must be so small that it has been thought better to measure only one very small distance rather than two very great and nearly opposite distances.

In order to eliminate the effect of an unknown error of the equatoreal adjustment on the position-angles, two meridian marks placed in the focus of lenses of long focus will be employed, one for "telescope following," and one for "telescope preceding."

The declination axis being levelled by a spirit level, a single observation of each mark will give the azimuth and altitude of the pole of the instrument (the azimuth and inclination of the collimator and the horizontal flexure of the heliometer being known).

The error of zero of the position circle will be obtained by separating the lenses, and bringing the image of the collimating mark to bisect successively the cross webs, when the heliometer is turned on the declination axis: this observation should be made with the tube on both sides of the polar axis.

By these precautions it is believed that when the distance is small, the parallax determined by the position-angles will be equally reliable with that obtained from the distances; particularly as in small stars the elongation of the images produced by division of the object-glass is hardly perceptible.

There are still two sources of systematic error which must be carefully eliminated: the *first* arises from an error in the assumed motion of the planet; the *second* from the errors of division of the scale and the errors of the micrometer screw, since by the motion of the planet different divisions will be employed at rising and setting.

With regard to the *first* of these, we are assured by Mr. Hind that it will be possible, by the existing observations of the planet, so to correct the present tables that not the smallest error is to be feared from this cause.

With regard to the *second*, it is not necessary for our purpose to ascertain the *absolute* division error of every interval. The division errors of our heliometer scale, as we shall presently

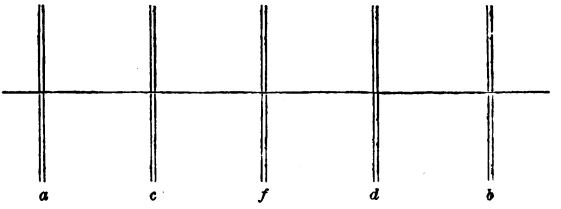
Digitized by Google

show, have been investigated for all divisions which occur in the measurement of angles up to 40′, with every desirable accuracy, so that it will only be necessary to compare the divisions passed over during the night's observation with several divisions whose interval is known.

The errors of the screw are now being investigated in a manner similar to that so successfully employed by the late Prof. Kaiser at Leiden, and though the results are not yet completed, there is no doubt it is simply a question of time and care to ascertain these errors with any accuracy that is required.

In the determination of errors to which we have alluded, a portion of each scale from division 50 to division 98 has been selected.

In the moveable wire frame of the micrometer Mr. Simms inserted at our request double webs as follow:



The space from a to b being slightly less than twelve divisions, and that from c to d slightly less than six divisions.

The first process was to subdivide each scale into four parts of twelve divisions each: the interval of a twelve-division interval exceeding the interval $a\,b$ by an amount $= n^1\,n^2\,n^3\,n^4$ successively. Then the true length of a 4th part of scale A will be $a\,b + \frac{n^1 + n^2 + n^3 + n^4}{4}$: the difference of $a\,(b + n^1)$ from a 4th part of scale A is the excess of the length of the interval 50–62 over $\frac{\text{Scale A}}{4}$.

In Table I., 1st, 2nd, 5th series, column 1, will be found these excesses of the intervals found by different series of observations in terms of the micrometer screw. The same point of the screw being used throughout, no error will result from this cause: the weights depend partly on the number of observations, and partly on the method of making the observations; but as the full details will afterwards be published, we need not further allude to them at present.

The results of the 5th and 7th series are derived from observations made with the wires of interval $c\,d$, that is, by dividing the scale into 8 parts: the weight of this series has been made one half the other, in proportion to the number of observations. We believe this weight should be still less.

Column 2 gives the difference from mean in *seconds of arc*,

Digitized by Google

and the accuracy of the observations may be judged of from the amount of these residuals.

Table II. similarly exhibits the results of subdivision into intervals of six divisions; and Table III. that of subdivision into intervals of three divisions: in the case of the latter, instead of the residuals, we give the probable error of the bisection of the interval of six divisions in *seconds of arc*.

From these we obtain the successive division errors for each third division reckoned from 50 towards 98, in seconds of arc,*

Scale A 0·000 + 0″·162 + 0″·242 + 0″·017 + 0″·205 + 0″·242 + 0″·266 + 0″·315 + 0″·013 + 0″·113 + 0″·168 + 0″·117 + 0′·108 − 0″·048 − 0″·027 − 0″·038 : 0·000.

Scale B 0·000 − 0″·060 + 0″·113 + 0″·138 + 0″·010 + 0″·088 + 0″·161 + 0″·027 + 0″·152 + 0″·074 + 0″·212 + 0″·217 − 0″·662 − 0″·062 − 0″·021 + 0″·011 ± 0·000.

If we look at these division errors, we see how very beautifully the scales are divided, and yet how much in a delicate enquiry like the present our systematic errors would be increased by disregarding them.†

We cannot pretend to predict what the probable error of a series of observations on the parallax of *Juno* will be, but if on 25 nights we can determine, as we believe we can, the place of the planet to 0″·1, the resultant error in the solar parallax will be about

$$\frac{\frac{8\cdot9}{12} \times 0''\cdot1}{\sqrt{25}} = 0''\cdot017$$

and we believe that this method is capable, with the precautions we have given, to give a result exceeding in accuracy that by any other method, if a sufficient number of observations on a number of different planets could be obtained.

* 1 Division is equal to 2 revolutions of the micrometer screw, and 1 revolution of the micrometer screw is approximately = 25″·74.

† We have been led to give more fully than we otherwise should have done in the present paper some account of the determination of these division errors, from a remark of the Astronomer Royal, contained in his Report to the Board of Visitors, read June 3, 1873. Sir George Airy says, "My present impression is one of doubt on the certainty of equality of the parts of the scale employed." If we take even the uncorrected scale the probable error of a division hardly exceeds that of an error of four seconds of time in an observation of contact in the transit of *Venus*, and the fact that eight divisions are used in each measurement diminishes the probable error to a much smaller amount. We have not had time to fully compute the probable error of determination of the division error of each scale, but Tables I., II., and III. show it cannot exceed 2 or 3 hundredth parts of a second of arc.

Digitized by Google

Excesses of Division Intervals.

Scale A. TABLE I.

	Weight	50–62		62–74		74–86		86–98	
		1	2	1	2	1	2	1	2
			″		″		″		″
1st series	12	+0107	0·069	−0080	0·013	+0032	0·013	−0059	0·044
2nd series	12	+0085	0·013	−0066	0·023	+0021	0·041	−0040	0.005
5th series	2	+0055	0·064	−0045	0·077	+0042	0·013	−0052	0·026
6th series	32	+0080	0·000	−0079	0·010	+0046	0·023	−0047	0·013
7th series	8	+0035	0·116	−0068	0·018	+0031	0·015	+0002	0·113
		+0080		−0075		+0037		−0042	

Scale B. TABLE I.

	Weight	50–62		62–74		74–86		86–98	
		1	2	1	2	1	2	1	2
			″		″		″		″
1st series	12	+0045	0·018	+0034	0·033	−0037	0·005	−0042	0·046
2nd series	12	+0021	0·044	+0020	0·003	−0025	0·026	−0016	0·021
5th series	2	+0030	0·021	+0002	0·049	−0032	0·008	−0000	0·062
6th series	32	+0053	0·031	+0020	0·003	−0042	0·018	−0028	0·010
7th series	8	+0009	0·075	+0009	0·031	−0016	0·049	−0002	0·057
		+0038		+0021		−0035		−0024	

Digitized by Google

Scale A. TABLE II.

	Weight	50–56		56–62		62–68		68–74		74–80		80–86		86–92		92–98	
		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
3rd series	1	+0050	0″010	−0050	0″010	+0083	0″057	−0083	0″057	+0042	0″000	−0042	0″000	−0032	0″003	+0032	0″003
4th series	1	+0069	0·039	−0069	0·039	+0074	0·033	−0074	0·033	+0035	0·018	−0035	0·018	−0018	0·033	+0018	0·033
5th series	1	+0053	0·003	−0053	0·003	+0092	0·080	−0092	0·080	+0036	0·015	−0036	0·015	−0002	0·075	+0002	0·075
7th series	2	+0049	0·013	−0049	0·013	+0028	0·085	−0028	0·085	+0048	0·015	−0048	0·015	−0053	0·057	+0053	0·057
Error of interval in terms of series.		+0054	...	−0054	...	+0061	...	−0061	...	+0042	...	−0042	...	−0031	...	+0031	...

Scale B. TABLE II.

	Weight	50–56		56–62		62–68		68–74		74–80		80–86		86–92		92–98	
		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
3rd series	1	+0050	0″064	−0050	0″064	+0022	0″021	−0022	0″021	−0005	0″118	+0005	0″118	+0036	0″021	−0036	0″021
4th series	1	+0001	0·061	−0001	0·061	+0006	0·021	−0006	0·021	+0028	0·033	−0028	0·033	+0033	0·013	−0033	0·013
5th series	1	+0029	0·010	−0029	0·010	+0025	0·028	−0025	0·028	+0061	0·051	−0061	0·051	+0041	0·033	−0041	0·033
7th series	2	+0022	0·007	−0022	0·007	+0009	0·013	−0009	0·013	+0055	0·036	−0055	0·036	+0016	0·031	−0016	0·031
Error of interval in terms of series.		+0025	...	−0025	...	+0014	...	−0014	...	+0041	...	−0041	...	+0028	...	−0028	...

Digitized by Google

Scale A. TABLE III.

	50–53	53–56	56–59	59–62	62–65	65–68	68–71	71–74	74–77	77–80	80–83	83–86	86–89	89–92	92–95	95–98
1st series . .	+0032	−0032	−0078	+0078	0000	0000	+0052	−0052	+0010	−0010	+0001	−0001	−0055	+0055	−0025	+0025
2nd series. .	+0094	−0094	−0042	+0042	−0032	+0032	+0047	−0047	+0026	−0026	+0001	−0001	−0035	+0035	−0015	+0015
Probable error	0″·056	0″·056	0″·033	0″·033	0″·029	0″·029	0″·005	0″·005	0″·015	0″·015	0″·000	0″·000	0″·018	0″·018	0″·009	0″·009

Scale B. TABLE III.

	50–53	53–56	56–59	59–62	62–65	65–68	68–71	71–74	74–77	77–80	80–83	83–86	86–89	89–92	92–95	95–98
1st series . .	−0015	+0015	+0024	−0024	−0017	+0017	−0048	+0048	−0050	+0050	+0015	−0015	−0002	+0002	+0030	−0030
2nd series. .	−0032	+0032	+0020	−0020	−0005	+0005	−0042	+0042	−0051	+0051	+0022	−0022	−0026	+0026	+0023	−0023
Probable error	0″·015	0″·015	0″·004	0″·004	0″·011	0″·011	0″·005	0″·005	0″·001	0″·001	0″·006	0″·006	0″·022	0″·022	0″·006	0″·006

Digitized by Google

List of Stars to be observed with Juno.

Name of Star.	Mag.	Mean R.A. 1874, Jan. 1. h m s	Mean Decl. 1874, Jan. 1. ° ′ ″	Name of Star.	Mag.	Mean R.A. 1874, Jan. 1. h m s	Mean Decl. 1874, Jan. 1. ° ′ ″
a	7–8	3 20 22	−0 24 8	*x*	8–9	3 5 43	−2 55 1
b	8–9	3 18 25	+1 31 9	*y*	6–8	3 5 15	−0 58 0
c	8–9	3 18 14	+0 54 6	*z*	6–7	3 5 1	−4 17 1
d	7	3 17 7	+0 28 0	*α*	7–8	3 3 55	−2 10 3
e	9	3 14 45	−0 58 7	*β*	9	3 3 7	−3 42 8
f	8–9	3 13 39	−2 2 9	*γ*	8	3 2 42	−4 7 6
g	7–8	3 13 32	+1 1 6	*δ*	9	3 2 26	−4 10 0
h	7–8	3 13 16	+0 44 5	*ε*	9	3 2 28	−4 4 4
i	7–8	3 12 38	−3 17 7	*ζ*	8–9	3 1 6	−5 52 2
k	5–6	3 11 54	−1 23 2	*η*	6–8	3 0 50	−2 17 1
m	8–9	3 9 3	−2 38 5	*θ*	8	2 57 55	−4 49 1
n	9	3 9 7	−0 56 6	*ι*	7	2 57 53	−5 44 0
o	7–8	3 8 13	−2 48 1	*κ*	8–9	2 53 48	−4 10 3
p	8	3 7 33	+0 16 2	*λ*	8	2 52 24	−4 42 7
q	9	3 6 30	−0 51 4	*μ*	8–9	2 50 26	−5 51 5
r	8–9	3 6 23	−3 22 7	*ν*	7	2 48 22	−5 50 4
s	5–6	3 6 19	−1 39 9	*χ*	7–8	2 46 58	−5 45 7
t	8–9	3 6 10	−3 28 3				

Date.	Star of Comparison.	Mag.	A. R. of M. P. h m s	Decl. of M. P. ° ′	4 Hours East. Position-Angle. ° ′	4 Hours East. Distance. ′	4 Hours West. Position-Angle. ° ′	4 Hours West. Distance. ′
Oct. 10	*b*	8–9	3 17 3	+1 28	80 47	31·9	67 36	33·5
	g	7–8	3 14 9	+1 13	240 0	49·0	244 30	45·8
Oct. 11	*c*	8–9	3 17 0	+1 3	121 20	36·0	123 43	35·5
	g	7–8	3 14 8	+1 6	253 50	41·5	259 29	39·3
Oct. 12	*c*	8–9	3 17 1	+0 56	99 49	35·0	92 49	36·0
	g	7–8	3 14 7	+1 0	272 21	36·0	279 2	35·7
Oct. 13	*d*	7	3 16 4	+0 37	132 23	28·8	123 25	27·0
	h	7–8	3 14 5	+0 45	264 41	36·5	272 35	35·1
			It is preferable to use *c* instead of *d* if height enough.					
	c	8–9	3 16 9	+0 50	79 55	38·9	73 44	41·2
Oct. 14	*d*	7	3 16 2	+0 30	103 55	26·2	93 1	26·8
	h	7–8	3 14 3	+0 38	286 52	33·5	294 43	33·9
Oct. 15	*d*	7	3 16 1	+0 24	76 59	30·0	70 7	33·5
	h	7–8	3 14 2	+0 32	309 6	36·4	316 4	38·0

Digitized by Google

Date.	Star of Comparison.	Mag.	A. R. of M. P.	Decl. of M. P.	4 Hours East. Position-Angle.	4 Hours East. Distance.	4 Hours West. Position-Angle.	4 Hours West. Distance.	
			h m s	° ′	° ′	′	° ′		
Oct. 16	*a*	7–8	3 17 5	−0 10	103 2	89·9	108 40	90·0	
	p	8	3 11 1	+0 11	273 31	110·0	276 19	108·1	
Oct. 17	*a*	7–8	3 17 4	−0 16	103 10	91·3	99 55	92·4	
	p	8	3 11 0	+0 5	281 6	105·8	283 54	104·5	
Oct. 18	*a*	7–8	3 17 2	−0 22	94 36	95·0	91 52	97·0	
	p	8	3 10 8	−0 2	288 52	104·1	291 43	103·3	
Oct. 19	*a*	7–8	3 17 0	−0 29	86 50	101·0	84 50	103·5	
	p	8	3 10 5	−0 8	297 12	103·0	299 31	103·0	
Oct. 20	*a*	7–8	3 16 7	−0 35	80 11	108·2	78 20	111·5	
	p	8	3 10 3	−0 15	304 29	104·1	307 30	105·0	
Oct. 21	*e*	9	3 13 7	−0 58	96 5	30·0	88 5	32·0	
	n	9	3 10 9	−0 57	269 8	55·5	273 34	52·5	

It is doubtful, however, from moonlight if *n* and *e* can be observed, if so, take

	y	6–8	3 8 9	−0 58	268 58	113·8	271 3	111·0	
	* *y* / *η*	6–8 / 6–8	3 3 0	−1 38	219 38	104·0	219 38	104·0	
Oct. 22	*k*	5–6	3 12 0	−1 17	199 35	16·5	195 5	11·5	No other star conveniently situated, parallax will depend on position-angle.
Oct. 23	*k*	5–6	3 11 7	−1 23	145 14	4·9	77 35	5·5	
Oct. 24	*k*	5–6	3 11 5	−1 29	48 40	13·9	44 2	18·5	
	s	5–6	3 8 7	−1 38	264 12	74·5	267 58	71·5	
Oct. 25	*f*	8–9	3 12 1	−1 55	111 4	47·2	105 52	48·3	
	s	5–6	3 8 5	−1 44	274 31	67·0	278 38	64·0	

In the event of *f* being too faint to observe in moonlight, use *i*.

	i	7–8	3 11 6	−2 32	163 5	96·8	160 24	94·0	
Oct. 26	*f*	8–9	3 11 8	−2 1	95 55	52·0	91 36	55·2	
	s	5–6	3 8 2	−1 50	286 45	60·2	291 43	59·0	

If *f* found too faint, use *i*.

	i	7–8	3 11 3	−2 38	155 39	88·3	152 17	86·2	
Oct. 27	*i*	7–8	3 11 0	−2 44	146 36	82·7	143 7	81·7	
	s	5–6	3 7 9	−1 56	300 16	56·8	305 19	57·0	
Oct. 28	*i*	7–8	3 10 7	−2 50	135 24	79·5	132 7	79·0	
	a	7–8	3 6 4	−2 16	277 56	77·0	281 35	75·0	

* The distance y–η being nearly that of Juno–y, the change as shown by heliometric observation of the distance y–η, will probably be very nearly the correction to apply to observation of Juno with y.

Digitized by Google

Date.	Star of Comparison.	Mag.	A. R. of M. P.	Decl. of M. P.	4 Hours East. Position-Angle.	4 Hours East. Distance.	4 Hours West. Position-Angle.	4 Hours West. Distance.	
			h m s	° ′	° ′	′	° ′		
Oct. 29	*i*	7–8	3 10 4	−2 56	125 2	78·5	121 19	79·2	Measure first *i* & *a* next on if sufficiently bright, then *o* if there is time.
	a	7–8	3 6 0	−2 22	287 46	70·5	291 51	69·2	
	m	8–9	3 8 6	−2 36	121 21	12·0	98 45	14·0	
	o	7–8	3 8 2	−2 41	188 22	16·2	173 14	12·5	
Oct. 30	*o*	7–8	3 7 9	−2 47	121 0	9·5	93 20	10·7	*o* being so near the Planet, it is desirable to measure it as well as the opposite stars *i* and *a*.
	i	7–8	3 10 1	−3 2	114 23	81·1	111 18	81·0	
	a	7–8	3 5 7	−2 28	300 0	67·0	304 12	66·3	
Oct. 31	*o*	7–8	3 7 6	−2 52	68 51	17·9	63 13	22·5	
	x	8–9	3 6 3	−2 56	268 13	21·0	279 15	18·3	
	Should the star *x* be found too faint, use								
	i	7–8	3 9 8	−3 7	105 19	86·4	102 43	88·6	
	η	6–8	3 3 9	−2 37	291 32	102·3	294 13	100·3	
Nov. 1	*r*	8–9	3 6 3	−3 15	180 0	17·2	165 50	14·0	
	x	8–9	3 6 0	−3 1	314 7	15·0	332 16	15·8	
	Should these stars be found too faint, use								
	i	7–8	3 9 4	−3 12	97 14	94·8	94 54	97·0	
	η	6–8	3 3 5	−2 42	300 0	97·2	302 43	96·2	
Nov. 2	*t*	8–9	3 5 9	−3 23	155 6	14·0	132 54	13·0	
	x	8–9	3 5 7	−3 6	357 4	20·5	6 19	24·2	
	Take also, if possible,								
	o	7–8	3 6 9	−3 3	53 17	46·0	52 12	51·3	Near *γ* is *δ* (Mag. 9) a little farther from *o*; do not observe this.
	γ	8	3 4 1	−3 43	222 6	69·0	221 49	63·9	
Nov. 3	*r*	8–9	3 5 6	−3 25	81 12	20·0	74 13	25·0	Care must be taken not to observe the rather brighter star *t* near *r*.
	β	9	3 4 0	−3 35	241 18	35·0	244 30	29·0	
	If *r* and *β* are too faint, observe								
	o	7–8	3 6 5	−3 8	51 10	60·2	43 41	66·0	
	γ	8	3 3 7	−3 48	221 32	54·5	220 56	49·0	
Nov. 4	*t*	8–9	3 5 2	−3 33	74 2	27·5	70 25	31·7	
	β	9	3 3 5	−3 40	252 13	20·7	258 25	16·6	
	Observe also								
	x	8–9	3 4 9	−3 16	25 29	45·6	27 58	50·0	
	γ	8	3 3 4	−3 53	218 55	40·1	218 25	35·6	
Nov. 5	*z*	6–7	3 4 3	−4 2	147 41	36·0	130 51	36·3	
	β	9	3 3 3	−3 45	290 32	9·8	317 45	8·9	
	If *β* is too faint, observe								

Digitized by Google

Date.	Star of Comparison.	Mag.	A. R. of M. P.	Decl. of M. P.	4 Hours East. Position-Angle.	4 Hours East. Distance.	4 Hours West. Position-Angle.	4 Hours West. Distance.	
			h m s	° ′	° ′		° ′		
	γ	8	3 3 1	−3 58	216 4	26·0	214 4	21·5	
Nov. 6	β	9	3 3 1	−3 50	4 37	13·5	17 31	17·4	Care must be taken not to observe the rather brighter star γ near δ.
	δ	9	3 2 6	−4 3	212 45	17·0	215 36	12·6	
			If β and δ are too faint, observe						
	ε	6–7	3 3 9	−4 7	125 28	37·0	117 43	39·0	
	η	6–8	3 1 6	−3 7	341 16	104·0	343 41	106·0	
Nov, 7	δ	9	3 2 3	−4 8	160 4	5·3	113 0	5·7	
	ϵ	9	3 2 3	−4 5	279 13	3·0	9 15	3·1	
			If δ and ϵ are too faint, observe						
	ε	6–7	3 3 6	−4 11	106 16	42·2	102 10	45·2	
	θ	8	3 0 0	−4 28	234 58	79·5	236 50	74·4	
Nov. 8	ε	6–7	3 3 2	−4 16	94 37	51·1	90 2	55·0	
	θ	8	2 59 7	−4 32	237 9	66·0	239 15	60·8	
Nov. 9	ε	6–7	3 2 9	−4 20	85 22	61·9	83 41	65·8	
	θ	8	2 59 3	−4 36	238 59	52·5	239 6	48·0	
Nov. 10	ε	6–7	3 2 5	−4 25	80 12	73·3	78 27	77·2	
	κ	8–9	2 56 9	−4 21	281 34	98·0	283 36	95·0	
Nov. 11	ε	6–7	3 2 2	−4 29	75 29	87·0	74 48	90·1	
	λ	8	2 55 8	−4 41	267 42	107·5	268 52	102·8	
Nov. 12	θ	8	2 58 2	−4 48	75 30	13·8	83 58	10·0	
Nov. 13	θ	8	2 57 9	−4 51	318 43	4·5	4 37	5·8	
Nov. 14	ζ	8–9	2 59 1	−5 26	133 38	76·5	130 42	77·6	
	λ	8	2 54 9	−4 51	282 25	77·0	284 31	74·0	
Nov. 15	ζ	8–9	2 58 6	−5 30	125 6	80·0	122 42	81·5	
	λ	8	2 54 5	−4 55	289 27	68·8	291 46	67·0	
Nov. 16	ζ	8–9	2 58 1	−5 33	118 22	85·0	115 48	87·5	
	λ	8	2 54 2	−4 58	297 12	62·5	300 40	60·5	
Nov. 17	ι	7	2 56 6	−5 31	126 40	46·4	122 41	47·4	
	λ	8	2 53 7	−5 0	308 23	56·6	310 19	55·6	
Nov. 18	θ	8	2 56 3	−5 6	54 33	58·4	55 36	62·3	
	μ	8–9	2 52 5	−5 37	249 1	72·2	249 1	67·7	
Nov. 19	θ	8	2 56 0	−5 9	56 38	69·4	57 15	72·5	
	μ	8–9	2 52 2	−5 49	249 1	61·2	249 1	57·3	
Nov. 20	ι	7	2 55 6	−5 38	101 1	67·3	99 51	69·7	
	ν	7	2 50 9	−5 41	256 17	80·2	257 6	77·0	
Nov. 21	ν	7	2 55 3	−5 49	96 55	75·7	95 50	77·6	
	ν	7	2 50 6	−5 42	257 49	70·5	258 25	66·8	

Digitized by Google

Date.	Star of Comparison.	Mag.	A.R. of M.P.	Decl. of M.P.	4 Hours East. Position-Angle.	4 Hours East. Distance.	4 Hours West. Position-Angle.	4 Hours West. Distance.
			h m s	° ′	° ′	′	° ′	
Nov. 22	ι	7	2 55 0	−5 42	93 55	83·7	92 18	86·9
	χ	7-8	2 49 6	−5 43	265 24	81·2	266 23	78·0
Nov. 23	ι	7	2 54 7	−5 43	90 28	91·3	89 49	94·2
	χ	7-8	2 49 3	−5 44	267 8	73·0	268 34	70·0
Nov. 24	ι	7	2 54 4	−5 45	89 15	100·0	88 48	103·1
	χ	7-8	2 49 0	−5 46	270 0	64·5	270 24	61·3
Nov. 25	μ	8-9	2 50 5	−5 50	218 39	5·7	187 11	3·4
Nov. 26	μ	8-9	2 50 3	−5 51	115 2	4·6	98 6	8·0
Nov. 27	μ	8-9	2 50 0	−5 52	90 52	11·8	90 0	14·3
	ν	7	2 49 0	−5 51	272 25	20·5	274 25	17·8
Nov. 28	μ	8-9	2 49 8	−5 52	87 33	19·7	85 31	21·3
	χ	7-8	2 49 0	−5 49	281 25	33·9	283 0	32·6
Nov. 29	ν	7	2 48 8	−5 52	299 52	6·3	315 48	5·2
Nov. 30	ν	7	2 48 3	−5 52	11 22	4·1	36 4	4·7

The places of the stars of comparison have been selected from the *Catalogues of the Berlin Equatoreal Star Charts*, for 2^h and 3^h A.R. by Morstadt and d'Arrest respectively, and reduced to 1874.

The A.R. and Decl. of the middle point between the planet and star (M.P.) is given for midnight at Mauritius, the position-angle and distance both for 4^h E. and for 4^h W. of the meridian at Mauritius. The places of the planet are those of the *Nautical Almanac* (Hind's Elements) reduced to the longitude of Mauritius.

Effect of Error in the Tabular Place of Venus, as deduced from Observations near the Ascending Node in 1872 *and* 1873, *at the Royal Observatory, Greenwich, on the time of Ingress and Egress,* 1874, *December* 8. By W. H. M. Christie, Esq.

The observed errors of Geocentric Longitude and E.P.D. must first be reduced to errors of Heliocentric Longitude, and E.P.D. by multiplying by the appropriate factors; then, on the assumption that the Heliocentric Errors at the Transit of 1874, December 8, will be the same as at the passages through the ascending node in 1872 and 1873, the errors of Heliocentric Longitude and E.P.D. previously found are to be converted into errors of Geocentric Longitude and E.P.D. for the Transit by multiplying them by the factors − 2·725 and + 2·725, respectively.

The effect of these errors in altering the distance between the centres of the Sun and *Venus*, at ingress and egress, will be found by resolving along the corresponding radii of the Sun.

Digitized by Google